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EXPERIMENTS WITH SPRAY SOLUTIONS FOR PREVENTING INSECT INJURY TO GREEN LOGS.

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USES FOR REPELLENT SPRAYS AGAINST FOREST AND SHADE-TREE INSECTS.

During the past few years there has been an increasing demand for a practical spray that will prevent insect attack to crude forest products such as green saw logs and timbers used in rustic construction. Numerous requests for such a spray are received by the Bureau of Entomology. These inquiries often number more than a hundred through the summer months.

Although many lumbering firms request a spray for this purpose, it is doubtful whether it would be really practical under ordinary conditions. During the flight period of those insects which cause the injury it would be necessary to apply the spray immediately after felling the trees. It is more practical to prevent insect injury in lumbering operations by some alteration in the methods of management, as by more prompt handling between felling and sawing or by submerging the logs in water, than by spraying.

[1] Resigned December 31, 1920.

Frequently, however, storms blow over many millions of feet of saw timber. Cases are on record where a single firm has lost in such a manner 100,000,000 board feet. It is a physical impossibility to log these trees promptly and get them to the saw or into a place of safety, although from 40 to 60 days' delay may mean total destruction of the sapwood by borers. It might be feasible, however, to saw these trees into log lengths and spray with some solution that would prevent insect attack for two or three months, or until it was possible to haul them to the mill.

The increasing use of the national forests and parks for recreational purposes has resulted in the construction of many rustic cabins. Insects attacking the timbers in these buildings cause annoying exudations of boring dust and loosen the bark so that later it peels off, thus marring the artistic effect. Much of this injury to rustic work could be prevented by cutting the trees at certain periods and by proper seasoning. Frequenters of summer camping grounds can not always plan to cut the trees at the proper time; in fact, it is more frequently the case that the building is constructed during the summer months and the timber felled at that time—a period when the wood is most susceptible to insect attack.

Thus in both situations it is often the case that the more practical and economical means can not be used.

There is also a considerable demand for a suitable repellent spray against certain shade-tree insects. Wood borers attack various species of living trees, causing considerable injury or death. Under certain circumstances a spray could be used advantageously to repel such insects and prevent oviposition. It would necessarily have to be of materials that would not burn the younger bark, although, except for mechanical difficulties, it would only be necessary to apply the spray to the main trunk and larger limbs, since these are the only parts attacked. Spray materials, the cost of which would be prohibitive for the protection of forest products, might be employed on shade trees.

Under circumstances such as the foregoing it is evident that a practical spray for the prevention of insect injury would be of much benefit and its use should result in a considerable saving of forest products and shade trees.

Owing to the many different insects, their different methods of attacking the logs, the many kinds of wood to be protected, and the exposure to weather conditions, the practical solution of this problem presents many difficulties. Several solutions have been found to meet the requirements, except that they are too expensive or too difficult to apply. In the hope that the results so far obtained may be a stimulus for further suggestions or work along this line the

problem and the preliminary experiments conducted during the years 1916 to 1919 are here presented.

REQUISITES OF A PRACTICAL SPRAY.

It may be impossible to find a single spray solution that can be used with success under all conditions, but it may be possible to obtain good results by using several solutions, each of which is effective under certain conditions. Any spray to fulfill all the requisites necessary for practical effectiveness must possess the following qualities:

IT MUST BE EFFECTIVE AGAINST SEVERAL TYPES OF INSECTS.

Many species of insects attack green timber. Some attack only certain kinds of wood while others show little discrimination. In some cases the injury is caused by the grubs or larvæ feeding beneath the bark or in the wood, or by an adult which bores through the bark and produces larvæ that feed under the bark. According to their method of attacking the wood, boring insects may be divided into the following four groups:

Type 1. Those that lay eggs in crevices of the bark. The larvæ hatching from these eggs then bore through the bark and later into the wood.

Type 2. Those that gnaw a hole through the bark and insert the egg beneath. The larvæ start feeding directly beneath the bark and later bore into the wood.

Type 3. Those that bore through the bark and wood as beetles, to make a suitable place for developing a new brood. The grubs in this case never cause injury.

Type 4. Those that bore through the bark as beetles and lay the eggs beneath the bark. The resulting larvæ feed beneath the bark and loosen it.

The only spray that could possibly be effective against all these types would be one of a disagreeable odor acting as a repellent, thus driving away the adult beetles and preventing oviposition. Poison sprays that will penetrate the outer layers of bark will kill the young larvæ of type 1, but experiments have demonstrated that such materials are not effective against types 2, 3, and 4. In these types most of the beetles do not eat any of the bark or wood as they chew through it and consequently are not poisoned. Possibly a poison combined with a sticky substance that would form a film over the bark and adhere to the mouth parts of the insects might kill them.

Insects of type 4 are not very injurious to saw logs, as they only work beneath the bark and do not enter the wood, but they are important in loosening the bark from rustic work. The others are all injurious to both classes of timber.

IT MUST BE EFFECTIVE ON VARIOUS SPECIES OF WOOD.

The type of bark makes considerable difference in the application of a spray. A bark which is very absorbent, such as that of ash or juniper, readily takes a spray; on the other hand, a smooth bark, such as beech or hickory, will absorb scarcely any of it. Such smooth bark does not hold the spray well but allows it to be easily washed off in the rain. In the latter case poison sprays would hardly be effective. The irregularities of the bark and all crevices must be thoroughly covered.

IT MUST NOT BE LEACHED OFF BY RAIN OR OTHER WEATHER CONDITIONS.

One of the greatest difficulties in the experiments to find an effective spray has been that the solutions are soon washed off by rain. Many of those tried were effective for a few weeks, or until the first hard rain, after which the trees were immediately attacked.

IT MUST NOT BE EXPENSIVE.

Since a considerable quantity of liquid is required to cover a large log by spraying, it naturally follows that the material must be inexpensive or it can not be used. Creosote oil, the most effective material so far tried, is far too expensive. It can be diluted, however, with as much as 4 parts of kerosene, thus materially reducing the cost of the spray without diminishing its effectiveness. For rustic work a much more costly spray can be used than on logging operations.

IT MUST FIRST PREVENT ALL INSECT INJURY FOR FROM ONE TO THREE MONTHS AT LEAST.

Three months' protection by the spray would be sufficient for most purposes. It is usually possible to get logs to the mill or into a place of safety within that time. If it were sufficiently cheap so that a second and perhaps a third application could be made, the solution would need to be effective for only one month; the necessity for more than one application, however, would of course be a handicap. In many cases three months' prevention of damage would carry the tree or log through the danger period—that in which the insect is flying—and natural seasoning during the ensuing winter would prevent further injury.

EXPERIMENTS WITH PREVENTIVE SPRAYS.

During the period of insect activities in the years 1916 to 1920, inclusive, series of experiments were conducted at the Eastern Field Station of the Bureau of Entomology, East Falls Church, Va., to determine the effectiveness of various solutions. These were

materials recommended by various correspondents or suggested by the forest insect personnel. Dr. J. K. Haywood, chairman of the Insecticide and Fungicide Board, United States Department of Agriculture, also gave some very interesting suggestions.

These experiments are to be considered as only of a preliminary character. The objects were chiefly to determine the requisites of an effective spray and to study the behavior of the different types of insects in relation to various treatments and methods of application, as well as to find an effective spray.

The solutions were tried principally on two kinds of wood—pine and ash—although occasionally hickory, juniper, and oak were used. The wood was cut at a time to give the most favorable condition for insect attack—hickory and juniper about January 1, pine and ash about March 15. It was treated immediately or held in a wire insectary until treated. The individual pieces of wood used were 3 feet long and averaged from 6 to 10 inches in diameter.

Insects of all types were represented in the tests. The following were the most abundant and economically the most important: *Neoclytus erythrocephalus* Fab. on ash and hickory, *Xylotrechus colonus* Fab. on oak and hickory, *Asemum moestum* Hald. on pine, *Cyllene pictus* Drury on hickory, and *Hylotrupes ligneus* Fab. on juniper—all of type 1; *Monohammus scutellatus* Say and *M. titillator* Fab. on pine—both of type 2 (no species of type 2 on other woods); various species of Ips, Phloeosinus, and Hylesinus on pine, juniper, and ash, respectively—of type 4; various species of ambrosia beetles on pine and oak of type 3.

From the foregoing it is seen that pine was tested against all four types; ash against types 1, 3, and 4; hickory against type 1; juniper against types 1 and 4; and oak against types 1 and 3. Owing to the seasonal variations in the abundance of the various species of insects the tests were not conclusive every season. For example, in 1918 and 1919 Monohammus was very abundant and attacked all the controls as well as many treated woods, while in 1920 very few were present and not all control logs were attacked. Again, in 1918 Hylesinus (type 4) in ash was abundant, though in 1920 very few of the control logs were attacked. Every year, however, some one type was very abundant on all species of wood used.

The flight period of these insects has a certain bearing on the results, as those species flying late in the season found the logs after they were exposed to weathering for a month or more. Most of the treatments were made about April 1, or 15 days before the flight of the first insects, and unless otherwise stated this time of treatment is to be inferred. With certain materials treatments were made also on June 1 at the time of the first flight of some other species. The flight periods are given in Table I.

TABLE I.—*Flight periods of beetles used in experiments for the protective treatments of woods with spray solutions.*

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Woods.
Neoclytus erythrocephalus, type 1.			———	———	———			Oak, ash, hickory.
Xylotrechus colonus, type 1.			———	———	———	———		Oak, hickory.
Arrhenodes minutus, type 1.		———						Pine.
Monohammus titillator and *M. scutellatus*, type 2.			———	———	———			Pine.
Ambrosia beetles, type 3.	———	———	———	———	———	———	———	All woods.
Phloeosinus, Hylesinus, and Ips, type 4.	———	———	———	———	———	———	———	Juniper, ash, pine.
Cyllene pictus, type 5.		———	———					Hickory.
Hylotrupes bajulus, type 5.		——						Juniper.

In the extreme northern States the flight period of these insects begins from two to four weeks later. In the Southern States the flight period extends approximately from March 15 to November 1 for all species except *Cyllene pictus*.

Two methods of application were employed—spraying and dipping. Dipping on the whole proved the more effective, as every crevice in the bark was reached; it was also more economical, as a smaller quantity of the solution was required. A round-bottomed galvanized trough requiring only 1 inch of solution in the bottom was used for this purpose. The logs were revolved in the trough until all sides came in contact with the liquid. When carefully done, however, spraying was nearly as effective as dipping and answered very well for practical purposes. It required a fine discharge under strong pressure so that penetration in all crevices was secured.

The treated sticks were placed in several positions: (1) In shaded woods on the ground, (2) in the sun on the ground, and (3) on a platform off the ground in the sun. The location of the sticks had considerable bearing on the results. Those in the woods were always more heavily attacked and those off the ground in the sun least attacked. This can be explained by the more rapid seasoning of the wood off the ground in the sun, which thus offered less favorable conditions for beetle attack, and by the fact that many insects will not oviposit on the upper surface of logs directly exposed to the sun. The logs in the woods were likewise exposed to more humid conditions and the solutions probably leached off sooner. It follows that

the most severe conditions for dipping and spraying tests were presented by those logs in the woods on the ground, and for this reason the discussion of results obtained is based on the results in treated wood placed in this position. Where there was marked difference in the amount of sunlight or in the sun temperature special note is made of the fact.

The thickness of the bark had a certain bearing on the results. Thick-barked pine logs present much more favorable conditions for the attack of all insects concerned. In some cases a treatment was very effective on thin-barked pine logs whereas treated thick-barked logs became heavily infested. The effectiveness of a treatment, therefore, was judged by the results following in the case of thick-barked logs.

TREATMENTS AND RESULTS.

Creosote oil alone.—Pine and hickory dipped and sprayed. No attack three months after treatment, except a few insects of type 2 in cracks of sprayed stick.

Creosote oil and kerosene.—All mixtures of kerosene and creosote oil give a tarry precipitate which must be strained out or allowed to settle before the liquid is used in a spray pump. This material was suggested by Dr. A. D. Hopkins.

Equal parts creosote oil and kerosene.—Pine, ash, juniper, and hickory, sprayed and dipped. Results as in the case of creosote oil alone.

One part creosote oil and two parts kerosene.—Treatment as in the next preceding paragraph. Results as in the case of creosote oil.

One part creosote oil and three parts kerosene.—Pine logs dipped. No attack after three months.

One part creosote oil and four parts kerosene.—Pine logs dipped. No attack after three months.

One part creosote oil and eight parts kerosene.—Pine logs sprayed and dipped were attacked after two months by a few insects of type 4.

Creosote oil alone and mixtures of creosote oil and kerosene gave excellent results. Everything considered, much better results were obtained with them than with any other material. Mixtures of creosote oil containing from 1 to as many as 8 parts of kerosene were effective, and perhaps an even greater dilution would be effective on absorbent barks such as ash or juniper. These mixtures act as repellents in no cases were insects observed to oviposit where the liquid was present, and they "stand up" very well in wet weather.

One part water-gas tar distillate[a] *and three parts kerosene.*—Considerably more precipitate results from this mixture than from that of creosote oil and kerosene; consequently it is more troublesome to handle. Pine logs were sprayed and dipped. The results were similar to those with creosote oil.

One part coal-tar road surfacing material and three parts kerosene.—Pine logs dipped with this mixture were attacked after 35 days by insects of type 4 and after their condition was but little better than that of the controls.

[a] A distillate prepared from water gas.

Coal-tar emulsion (prepared by Insecticide Board); 1 part emulsion to 10 parts water.—Pine logs dipped and sprayed were attacked after 15 days by insects of type 4 and later by those of all types. Final results were no better than in the case of the controls.

Crude petroleum.—Pine logs sprayed and dipped with crude petroleum were attacked by insects of type 4 after 15 days and later by those of all types. Final results were no better than with the controls.

Anthracene oil emulsion (prepared by Insecticide Board); 1 part emulsion to 10 parts water and 1 part emulsion to 100 parts water.—Dipped pine logs were attacked by insects of type 4 after 15 days and later by those of all types. The final results were no better than with the controls.

Crude solvent naphtha.—Pine logs dipped with this material were slightly attacked by insects of type 4 after 15 days and later by all types. Final results were but little better than with the controls.

Six ounces of nitrobenzene in one gallon of kerosene.—Pine logs sprayed and dipped were attacked after 15 days by a few insects of type 4 and later by more of the same type. The final results were somewhat better than with the controls.

Fish oil.—Pine logs sprayed and dipped were immediately attacked by insects of type 4 and later by all types. Final results were no better than with the controls.

Two parts fish oil, one part pine oil, and three parts kerosene.—Pine logs sprayed and dipped were attacked after 15 days by insects of type 4 and later by all types. The final results were no better than with the controls.

Kerosene.—Pine logs sprayed and dipped were attacked after 15 days by insects of type 4 and later by all types; results were no better than with the controls.

Sulphite concentrate (furnished by a paper-pulp mill); full strength and diluted with equal parts of water.—Pine logs dipped were attacked after one week by insects of type 4 and later by all types. Final results were no better than with the controls.

Spent sulphite; full strength and equal parts spent sulphite and a commercial miscible oil.—The results in pine logs dipped and sprayed were the same as with sulphite concentrate.

Tree gum (furnished by Gipsy Moth Laboratory); 1 pound of tree gum dissolved in 1 quart of turpentine.—Pine logs treated with a brush were attacked by a few insects of type 4 after two months. The results were much better than on the controls, but the material held moisture in the log and produced much bluing of sap when insects penetrated the bark. The sticky film acted as a mechanical barrier.

One pound of melted paraffin with one gallon of gasoline added.—Pine, ash, and juniper logs were sprayed and dipped and placed in a cage for experiment against insects of type 4. This treatment prevented all attack on the more absorbent bark of ash and juniper. A few insects attacked the pine.

One-half pound of naphthalene dissolved in one gallon of gasoline.—Dipped pine logs were attacked after 15 days by insects of type 4 and later by all. Final results were but little better than with the controls. The naphthalene soon evaporates and no odor is left.

One pound of melted paraffin with one-half pound of naphthalene and one gallon of gasoline added.—Pine, ash, and juniper sprayed and dipped and placed in a cage against type 4 were attacked by insects of this type after 30 days.

One per cent sodium arsenate solution.—Juniper logs dipped and exposed against insects of types 1 and 4 were not attacked after 60 days.

Sixteen parts of 1 per cent sodium arsenate and one part of a commercial miscible oil.—Juniper dipped in this mixture was not attacked after 60 days, but dipped pine was heavily infested by type 4 after 15 days.

Stock solution of kerosene emulsion, the water used containing 2 per cent sodium arsenate.—Pine and hickory logs, sprayed, were attacked by all types possible. The final results were no better than with the controls.

One ounce of sodium arsenate dissolved in one pint of alcohol and added to one and one-half gallons of kerosene.—Very little arsenate went into solution. Pine logs, sprayed and dipped, were heavily attacked after 30 days by insects of type 4 and later by all types. Final results were but little better than in controls. Ash logs, sprayed and dipped, were attacked by one insect of type 1, but the final condition was much better than with the controls. This treatment was repeated on June 1 under similar conditions and with similar results.

One part arsenic acid to nine parts water followed by lime water (arsenic acid 30 per cent AS_2O_5 by weight, S. G. 1.3000, prepared by Insecticide and Fungicide Board.—Pine and ash logs were dipped. The pine was not attacked until 60 days and then by only a few insects of type 4. The ash was not attacked. This treatment, under similar conditions, was repeated June 1, and there was no attack after 60 days.

One-fourth ounce of corrosive sublimate dissolved in two and one-half ounces of alcohol and added to one and one-half gallons of kerosene.—Pine and ash were sprayed and dipped. The pine was first attacked after 40 days by a few insects of type 4; there was no other attack. The ash was not attacked. This treatment, repeated June 1 under similar conditions, gave the same results. Although these logs were not attacked by Monohammus of type 2, it is hardly safe to conclude that this treatment would always be effective against them.

Saturated solution of sodium fluorid.—Pine, ash, and hickory were sprayed and dipped. There was no attack for 30 days, and then the logs were infested by all types, though to a less degree than the controls. Little bluing was noted on pine. Although not altogether successful, this solution is worthy of further trial. This treatment, repeated June 1 with conditions as before, gave like results.

Saturated solution of sodium fluorid, 20 parts to one part of a commercial miscible oil.—Pine logs were dipped and sprayed with results as in the previous experiment.

Three ounces of zinc chlorid dissolved in three ounces of alcohol and added to one and one-half gallons of kerosene.—Pine and ash sprayed and dipped. The pine was attacked after 30 days by insects of type 4 and later by all types. Ash was not attacked by type 1. June 1 the treatment, under the same conditions, was repeated with results as before.

Five and ten per cent crude carbolic acid[3] *in water.*—Pine logs, sprayed and dipped, were immediately attacked and heavily infested by all types. The final results were no better than with the controls.

Two and one-half per cent solution crude carbolic acid in water, eight parts to one part of a commercial miscible oil.—Treatments and results as in the preceding paragraph.

Six ounces of carbolic acid in one gallon of kerosene.—Pine, sprayed and dipped, was attacked after 30 days by all types. The final results were no better than with the controls.

[3] Coal-tar oils and acids, 97 per cent; inert matter, 3 per cent.

Carbolic soap solution: One pint crude carbolic acid added to one gallon soft soap, thinned by addition of one gallon of hot water, left to stand overnight, and then diluted with eight gallons of soft water (recommended in literature).—Pine and ash, sprayed and dipped June 1, were attacked by all types after 10 days.

Five per cent solution of nicotine sulphate.—Pine, hickory, ash, and juniper were sprayed, and all were attacked by type 4 within 10 days.

Two teaspoonfuls nicotine sulphate dissolved in three ounces of alcohol and added to one and one-half gallons water.—Pine and ash, sprayed and dipped, were infested by all types after 15 days.

Ten per cent solution of sodium carbonate.—Pine and hickory logs sprayed were immediately attacked by all types possible.

Five per cent solution of a proprietary crude cresol-soap disinfectant.—Pine, juniper, ash, and hickory were sprayed but were all attacked by all types possible.

A strong suspension of whitewash.—Pine logs dipped were heavily attacked after the first rain.

A strong solution of sodium chlorid.—Pine logs sprayed were immediately attacked and their condition was no better than that of the controls.

One part crude pyridin preparation to ten parts water.—This did not mix well. Pine and ash were dipped June 1. After 30 days both woods were infested by all types possible, but were in somewhat better condition than the controls.

One part crude pyridin preparation to ten parts kerosene.—Pine and ash were dipped June 1. After 60 days no insects had attacked either wood. The odor could still be detected on the logs. This material seems to be very promising and deserves further trials.

REMARKS ON POISONS USED.

Several of the more active poisons seem to be effective against certain types of insects, particularly those of type 1. They are especially effective when combined with oils that will penetrate the bark (as the mixture of corrosive sublimate and kerosene) or followed by another solution rendering them insoluble (as arsenic acid followed by lime water). This latter, however, is difficult to apply. They are also more effective when used on absorbent types of bark as ash and juniper.

OTHER EXPERIMENTS WITH INSECTS OF TYPE 3.

The results of the preceding treatments were not conclusive against the ambrosia beetles (type 3) for two reasons: These insects require wood that is moist—at least such wood presents optimum conditions—in which to rear their broods. The logs used in the preceding experiments, averaging only 6 to 10 inches in diameter, often dried so rapidly that they were not suitable for these beetles. At the same time another series of experiments was being conducted in which water-soaked logs were used. These acted as traps, attracting most of the ambrosia beetles.

Consequently, to determine just how effective these solutions were against ambrosia beetles (Table II), the water-soaked logs were thoroughly sprayed with (1) 4 parts kerosene plus 1 part creosote oil, (2) the corrosive sublimate solution as given before, and (3) 1 part crude pyridin preparation to 8 parts kerosene. All the sticks were dried for 24 hours before the sprays were applied. These materials were applied to three pines, one oak, and one ash log, July 28, 1920. The results are given in Table II.

TABLE II.—*Results of experiments in the treatment of water-soaked logs against ambrosia beetles.*[1]

	Controls.			Kerosene and creosote oil.			Pyridin and kerosene.			Corrosive sublimate.		
	Pine.	Oak.	Ash.	Pine.	Oak.	Ash.	Pine.	Oak.	Ash.	Pine.	Oak.	Ash.
Aug. 3	1	1	7	0	0	0	0	0	0	0	0	1
9	0	1	23	1	0	0	0	0	1	0	0	3
13	1	3	27	0	0	0	0	0	0	0	5	6
22	5a	x	x	0	0	1	0	1	0	1a	4	16
27	1a	13	64	1	0	0	0	0	0	1a	0	10
Sept. 1	(2)	(2)	(2)	0	0	0	0	0	0	0	0	4
8	0	1	4	3a	0	0	0	0	1	2a	1	7
18	(2)	(2)	(2)	0	0	2	0	0	0	0	0	1
28	(2)	(2)	(2)	0	0	1	0	0	0	0	0	4
Total ambrosia beetles	2	19	125	2	0	4	0	1	2	1	10	52

[1] Numbers refer to ambrosia beetles attacking except when followed by letter.
[2] Not counted.
a=species of Ips, type 4. x=many ambrosia beetles not counted.

POISONING OF AMBROSIA BEETLES.

To determine whether ambrosia beetles feed on the bark as they bore through it, and consequently whether poison spray could be effective against them, several water-soaked ash logs were dried for 48 hours to remove the excess water from the bark and then completely submerged for 48 hours in a solution of sodium arsenate, 2 pounds to 10 gallons of water.

A wooden frame with a cheesecloth bottom was prepared on the ground, and on supports above this frame a rubber cloth was suspended to keep any rain from reaching the treated sticks. The sticks were placed in the box on the cheesecloth and the cloth was carefully examined every two or three days for dead ambrosia beetles. The treatments were made on May 30, 1920. An untreated control was used in the same position. The results were as follows:

June 8, one dead beetle beneath sticks.

June 15, one beetle boring through bark.

June 23, two beetles boring through bark.

July 23, two to six beetles were in each stick and all galleries contained eggs and various stages of larvæ.

These beetles were evidently not deterred or injured by the poison. At no time were the sticks wet. It is quite probable that the dead beetle found June 8 was not killed by the poison, since no other dead insects were found.

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